METHOD FOR MANUFACTURING LIQUID CRYSTAL DISPLAY DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method for manufacturing a liquid crystal display device, and particularly to a method for manufacturing a liquid crystal display device incorporating therein a plastic substrate as a substrate thereof.

2. Description of the Related Art

A plastic substrate has been considered a promising substrate material for compact, thin and low cost liquid crystal display device. Japanese Patent Application No. 13(2001)-125082 discloses a method for manufacturing a liquid crystal panel employing therein such a plastic substrate. The plastic substrate employed in the liquid crystal display device disclosed in the publication will be briefly explained with reference to FIGS. 1A through 2B.

As shown in FIG. 1A, first, a thermally activatable adhesive 212 attached with a removable film 211 is pressed against and attached to a support substrate 203 using a roller. Then, as shown in FIG. 1B, the removable film 211 is peeled off from the thermally activatable adhesive 212 attached to the support substrate 203. Furthermore, as shown in FIG. 1C, a plastic substrate 201 having a transparent electrode 213 formed on the surface of the substrate is adhesively attached using a roller 215 to the support substrate 203 via the thermally activatable adhesive 212.

The inventors of this application identified the following problems occurring when the plastic substrate fabricated as

described above is handled in actual manufacturing steps.

That is, referring to a side view shown in FIG. 2A, air 214 enters between the thermally activatable adhesive 212 and the plastic substrate 201. Even when trying to pull out the air left between the thermally activatable adhesive 212 and the plastic substrate 201, the adhesive 212 blocks a passage along which the air is pulled out to the outside and therefore, the air always is left therebetween. Thereafter, the plastic substrate 201 supported by the support substrate 203 is rinsed with pure water and chemical solution, and then dried at a temperature of 130-170.degree. C.. Then, an alignment material that is to be heated at low processing temperatures is applied to the transparent electrode 213 on the plastic substrate 201 by printing techniques and heated at a temperature of 80-180.degree. C.. Subsequently, the heated alignment material is rubbed to form an alignment film and rinsed with pure water, and then dried at a temperature of 130-170.degree. C..

The plastic substrate 201 having subjected to the aforementioned heat treatment is deformed because the air 214 thermally expands and grows as a large bubble. In some cases, the plastic substrate 201 is broken by expansion of bubble.

Moreover, as shown in FIG. 2B, an adhesive sealing material 204 provided as an thermally cured adhesive and having a specific pattern is formed on the surface (on the side of an alignment film) of the plastic substrate 201, which is supported by the support substrate 203, by screen printing techniques or dispensing techniques. Then, a TFT substrate 251 having spacers (not shown) dispersed on the surface thereof and the plastic substrate 201 supported by the support substrate 203 are attached

together along the edge with the adhesive sealing material 204 and the two substrates are pressed against each other, and further, heated for 1 to 2 hours at a temperature of 120-160.degree. C., resulting in attachment to each other.

The two substrates attached to each other as described above encounter a situation in which a cell gap between the two substrates becomes non-uniform, the adhesive sealing material is displaced from its original position, or the plastic substrate is subject to breakage. This is because variations in the extent to which the thermally activatable adhesive 212 is adhesively attached to the plastic substrate occur and/or the air 214 left between the thermally activatable adhesive 212 and the plastic substrate 201 and subjected to heat treatment in the step of sintering the sealing material expands, resulting in deformation and/or flexure of plastic substrate. Furthermore, the fact that the amount of expansion or shrinkage of plastic substrate 201 is larger than that of the support substrate 203 at high processing temperatures (i. e., during sintering of sealing material) also contributes to deformation and/or flexure of plastic substrate. That is, adhesion force of the thermally activatable adhesive 212 provided to the plastic substrate 201 cannot suppress expansion or shrinkage of plastic substrate.

Moreover, since the plastic substrate constructed as described above has the thermally activatable adhesive attached thereto, it needs to be processed through time-consuming steps including an attachment step and a peeling step, unfavorably increasing the number of process steps.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a method for manufacturing a liquid crystal display device that incorporates therein a plastic substrate that is free from deformation and/or flexure and never causes non-uniformity of a cell gap between two substrates during the step of attaching the two substrates to each other.

A method for manufacturing a liquid crystal display device according to the invention comprises: a step of pressing a first substrate and a support substrate against each other under vacuum conditions; a step of breaking the vacuum conditions and transferring the first substrate and the support substrate into an external atmospheric pressure environment while keeping the first substrate and the support substrate being pressed against each other to attach the first substrate and the support substrate to each other; a step of disposing the first substrate pressed against and attached to the support substrate and a second substrate so that the first substrate and the second substrate are aligned with each other while interposing a sealing material therebetween; and a step of curing the sealing material to attach the first substrate and the second substrate to each other via the sealing material.

The method for manufacturing a liquid crystal display device according to the invention is further constructed such that the step of pressing a first substrate and a support substrate against each other under vacuum conditions is performed by pressing the first substrate and the support substrate against each other so that a surface of an alignment film formed on the first substrate and a roughened surface previously formed on

a press tool are disposed to face each other.

The method for manufacturing a liquid crystal display device according to the invention further comprises a step of removing the support substrate from the first substrate after the step of curing the sealing material to attach the first substrate and the second substrate to each other, in which the step of removing the support substrate from the first substrate is performed by threading a thin strip between the first substrate and the support substrate.

The method for manufacturing a liquid crystal display device according to the invention further comprises a step of injecting a liquid crystal material into a space enclosed by the first substrate, the second substrate and the sealing material after the step of removing the support substrate from said first substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a side view illustrating how a conventional liquid crystal display device is manufactured in the order of process steps in a case where a liquid crystal display device employs a plastic substrate as one of two opposing substrates;

FIG. 1B is a side view illustrating the step subsequent to the step shown in FIG. 1A;

FIG. 1C is a side view illustrating the step subsequent to the step shown in FIG. 1B;

FIG. 2A is an enlarged side view illustrating a situation in which air bubble is left between the plastic substrate and an adhesive, and showing the step subsequent to the step shown in FIG. 1C;

FIG. 2B is a side view illustrating a situation in which a TFT substrate and the plastic substrate supported by the support substrate are attached together along the edge with the adhesive sealing material, and showing the step subsequent to the step shown in FIG. 1C;

FIG. 3A is a side view illustrating how a liquid crystal display device is manufactured according to the invention in the order of process steps in a case where a liquid crystal display device employs a plastic substrate as one of two opposing substrates;

FIG. 3B is a side view illustrating the step subsequent to the step shown in FIG. 3A;

FIG. 4A is a side view illustrating the step subsequent to the step shown in FIG. 3B;

FIG. 4B is a side view illustrating the step subsequent to the step shown in FIG. 3A;

FIG. 5A is a side view illustrating the step subsequent to the step shown in FIG. 4B; and

FIG. 5B is a side view illustrating the step subsequent to the step shown in FIG. 5A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An illustrative embodiment of a method for manufacturing a liquid crystal display device according to the present invention will be explained in the order of process steps with reference to cross sectional views shown in FIGS. 3A, 3B, 4A, 4B, 5A and 5B.

First, a plastic substrate 1 having an insulation film and an ITO film formed in order thereon and having a thickness

of 0.05 to 0.2 mm is prepared. When taking into account the situation in which the plastic substrate is to be attached to a support substrate in a subsequent step, the plastic substrate needs to have a smooth surface and therefore, is preferably made of polycarbonate (PC) or polyethersulfone (PES). The plastic substrate 1 is used as an opposing substrate disposed opposite an active matrix substrate (TFT substrate) in a liquid crystal display device. Accordingly, the plastic substrate of the embodiment may be configured to have color filters formed underneath the insulation film.

Thereafter, the plastic substrate 1 is rinsed with pure water and chemical solution, and then dried at a temperature of 130-170.degree. C.. Then, an alignment material that is to be heated at low processing temperatures is applied to the ITO film on the plastic substrate 1 by printing techniques and heated at a temperature of 80-180.degree. C.. Subsequently, the heated alignment material is rubbed to form an alignment film 2 and rinsed with pure water, and then dried at a temperature of 130-170.degree. C..

Then, as shown in FIG. 3A, the plastic substrate 1 is transferred to a vacuum chamber 100 and placed on a lower plate 101 within the vacuum chamber 100. The lower plate 101 has a roughened plate 102, which is processed to have surface roughness, previously disposed thereon. Thereafter, the plastic substrate 1 is placed on the lower plate 101 so that the alignment film 2 contacts a roughened surface of the roughened plate 102 on the lower plate 101. Additionally, an upper plate 103 is disposed to face the lower plate 101 within the vacuum chamber 100 and a glass substrate 3 provided as a support substrate for the plastic

substrate 1 and having a thickness of 0.5 mm to 1.0 mm is electrostatically attached to a surface, positioned on the side of the lower plate 101, of the upper plate 103. Thereafter, the vacuum chamber 100 is evacuated to a residual pressure of about 1.times.10.sup.-1 Pa.

Under the aforementioned conditions, the upper plate 103 having the glass substrate 3 electrostatically attached thereto is brought down upon the lower plate 101 and made to press the plastic substrate 1 placed on the roughened plate 102 on the lower plate 101 against the lower plate 101, as shown in FIG. 3B.

Subsequently, as shown in FIG. 4A, the vacuum conditions are broken and the components within the chamber are transferred into an external atmospheric pressure environment while the upper plate 103 is being pressed against the lower plate 101. Then, electrostatic charges on the upper plate 103 are neutralized and the upper plate 103 is lifted in a direction in which the upper plate 103 becomes apart from the lower plate 101, creating a situation in which the plastic substrate 1 is placed on the roughened plate 102 on the lower plate 101 while the glass substrate 3 is being pressed against and attached to a rear surface (a surface on which the alignment film is not formed) of the plastic substrate 1.

Under the aforementioned conditions, the plastic substrate 1 is peeled off from the roughened plate 102 as shown in FIG. 4B. In this case, the plastic substrate 1 can easily be removed from the roughened plate 102 making use of projections or depressions on the roughened surface of the roughened plate 102.

Thereafter, as shown in FIG. 5A, an adhesive sealing material 4 as a thermally curable adhesive is formed on a surface (on the side of the alignment film 2) of the plastic substrate 1, which is supported by the glass substrate 3, by screen printing techniques or dispensing techniques to have a specific pattern. The sealing material 4 preferably has an elastic modulus of not less than 1.5.times.10.sup.9 Pa. Then, a TFT substrate 51 having spacers (not shown) dispersed on the surface thereof and the plastic substrate 1 supported by the glass substrate 3 are attached together along the edge with the adhesive sealing material 4. Subsequently, the two substrates are pressed against each other and heated for 1 to 2 hours at a temperature of 120-160.degree. C., resulting in attachment to each other. In this case, the two substrates may be attached together through the sealing material 4 that is formed on a surface of the TFT substrate. Furthermore, when employing a UV-curable material as a sealing material, the plastic substrate is subjected to less thermal stress, further enhancing its flatness.

Thereafter, as shown in FIG. 5B, a thin strip 5 such as a cutter blade is inserted and threaded between the glass substrate 3 and the plastic substrate 1, allowing the glass substrate 3 and the plastic substrate 1 to be peeled off from each other. Then, a liquid crystal material is injected into a space between the plastic substrate 1 and the TFT substrate 51 via a liquid crystal injection port (not shown) under vacuum conditions, and the liquid crystal injection port is sealed with a sealant so as to provide a finished liquid crystal panel product.

The liquid crystal display device fabricated as described above has the following features.

First, the plastic substrate is attached to the support substrate under vacuum conditions and therefore, strongly and uniformly pressed against the support substrate as compared to the case where the plastic substrate is attached to the support substrate via an adhesive. This prevents the plastic substrate having a specific coefficient of linear expansion from thermally expanding or shrinking. Accordingly, the adhesive sealing material can be formed on the plastic substrate under the same conditions as those observed when the sealing material is formed on the glass substrate and further, the two substrates can be attached together to have a uniform cell gap therebetween.

Second, in the embodiment, the support substrate and the plastic substrate are directly attached together under vacuum conditions without interposing an adhesive therebetween. Since attachment surfaces of the support substrate and the plastic substrate are smooth, the two substrates can be attached together at the smooth attachment surfaces as a boundary under vacuum conditions. Accordingly, air never remains between the support substrate and the plastic substrate. Furthermore, since the plastic substrate is configured to prevent formation of projections or depressions on its surface, a distance between the two substrates does not locally change, permitting a cell gap between the TFT substrate and the plastic substrate, both substrates constituting the liquid crystal display device, to become uniform.

Additionally, the plastic substrate is peeled off from the support substrate by threading the thin strip between the two substrates and therefore, the peeling off of the plastic substrate can be performed very easily, contributing to reducing

the number of manufacturing steps.

When employing the method for manufacturing a liquid crystal display device according to the invention, the plastic substrate is attached to the support substrate under vacuum conditions and air bubble is generated between the plastic substrate and the support substrate with lower probability than in a case where the two substrates are attached together via an adhesive. In addition, the extent to which the plastic substrate is expanded or shrunk by heat generated when the sealing material is sintered is made far smaller than that observed when the plastic substrate attached to the support substrate via an adhesive is expanded or shrunk. Accordingly, even after the plastic substrate and the TFT substrate are attached together along the edge with the sealing material, the plastic substrate is able to maintain its flatness and therefore, the two substrates are spaced a uniform distance apart from each other, i. e., fabricated to maintain a constant cell gap therebetween as desired.